light. This was so decided, that had I been examining the stars in that region I should at once have singled out the *Nova* as different from any of the stars. The spurious disc appeared much duller and somewhat larger than that of a star, and of a slight yellowish colour."

As the new star has faded, this peculiarity has become even more striking. The light of the *Nova*, which is greenish white, is very much like that of *Neptune*, and when *Neptune* is seen with a power that just begins to show its disc, the general likeness to the *Nova* would be striking. The light, however, is more greenish than that of *Neptune*. It also strongly resembles *Ceres* when that planet is seen with not too high a power. The colour is also like some of the planetary nebulæ—especially N.G.C. 7662 in *Andromeda*. While the light from a star is vivid, that of *Nova Persei* is singularly dull with high powers.

Yerkes Observatory, Williams Bay, Wisconsin:
1902 *February* 5.

On the Variation of S Carinæ. By Alex. W. Roberts, D.Sc.

There are at present (February 1902) between 160 and 180 stars south of $-30°$ dec., whose variation is known with some degree of certainty.

Of this number ten are of marked interest, as their variation was discovered and definite minima and maxima determined by Dr. Gould. The star *S Carinæ* (Ch. 3637) is one of these Cordoba variables. Inasmuch as I have already dealt with the variation of *R Carinæ* (*Monthly Notices*, vol. lxi. p. 552) and with the variation of *R Centauri* (*Monthly Notices*, vol. lxi. p. 355), both stars whose variation was discovered and defined by Dr. Gould, it will, I think, give a measure of completeness to these papers to consider also the variation of *S Carinæ*.

It may be noted here that the three stars are good examples of three well-defined types of long-period variation.

We consider in the first place the data which are of service as leading to a determination of the period of the star.

Dr. Gould's note on the variation of *S Carinæ* is as follows (*Uranometria Argentina*, p. 253):—

"The fluctuations of the light of this star appear to be within the limits $6\frac{1}{4}^{m}$ and a little above 9^{m}, and the length of its period to be several months. In 1872 its magnitude was observed as follows: T., May 26,* 7·0; April 3, 6·9; H., May 24, 30, 8·0; R., July 28, 7·9; Aug. 7, 7·4. In 1874 it was twice observed by Mr. Thome, May 21, 6·3; June 9, 7·3; observations which place the variability of the star beyond question.

* March 26?

"In May 1877 he estimated it as $8\frac{3}{4}^{m}$. Amid the great amount of other labour, sufficient observations have not been made to enable me to determine the light curve; but with the certainty of its variability I have not hesitated to designate it *S Carinæ*. Its colour is decidedly reddish."

Although Gould's observations are not sufficient to yield a period they are so situated on the light curve that they afford an indication of a definite date when the star passed through its maximum phase in 1872.

Later on in the present investigation this date will be determined and a period deduced from it. It is necessary first, however, to consider the more recent observations. These alone are sufficient to yield complete elements of variation, and thus they readily admit of being related to the Cordoba observations.

Observations of *S Carinæ* were begun at Lovedale in April 1891, and have been continued with one short interval down to the present. The number of observations secured during this period is close on 800. Nearly all the observations were made with a good 1-inch telescope, the usual precautions being taken to eliminate position error.

In the following two tables are given the several maxima and minima determined from the Lovedale observations. For purposes of computation the Julian day is given in the third column. In the fourth column is set forth the magnitude at maximum or minimum phase. In the last column is given the difference between these observed magnitudes and the mean magnitude for the whole series, viz. $6^{m}\cdot2$ for maximum and $8^{m}\cdot9$ for minimum.

TABLE I.

Determination of Maxima.

Rotation No.	Date.	Julian Day. J	Mag. m	Diff. m
1	1891 June 30	2411914	6·2	0·0
2	1892 April 17	2412206	5·8	−0·4
3	1893 Feb. 7	2412502	5·9	−0·3
4	June 30	2412645	5·9	−0·3
5	Nov. 30	2412798	6·0	−0·2
6	1894 May 9	2412958	6·6	+0·4
7	Sept. 27	2413099	6·0	−0·2
8	1895 July 21	2413396	5·7	−0·5
9	Dec. 28	2413556	6·7	+0·5
10	1896 May 21	2413701	6·0	−0·2
11	Oct. 16	2413849	5·8	−0·4
12	1898 Oct. 24	2414587	6·3	+0·1
13	1899 Mar. 28	2414742	6·6	+0·4
14	Aug. 20	2414887	6·3	+0·1

Rotation No.	Date.		Julian Day. J	Mag. m	Diff. m
15	1900 Jan.	24	2415044	6·6	+0·4
16	June	11	2415182	6·0	−0·2
17	Nov.	10	2415334	6·2	0·0
18	1901 April	7	2415482	6·4	+0·2
19	Aug.	29	2415626	5·8	−0·4
20	1902 Jan.	22	2415772	6·6	+0·4

Table II.

Determination of Minima.

Rotation No.	Date.		Julian Day. J	Mag. m	Diff. m
1	1892 Feb.	8	2412137	9·4	+0·5
2	July	6	2412286	9·2	+0·3
3	Nov.	19	2412422	8·8	−0·1
4	1893 May	3	2412587	9·0	+0·1
5	Sept.	20	2412727	8·7	−0·2
6	1894 Feb.	15	2412875	9·2	+0·3
7	July	15	2413025	9·3	+0·4
8	1895 May	13	2413327	8·7	−0·2
9	1896 Mar.	13	2413632	8·7	−0·2
10	Aug.	2	2413774	8·9	0·0
11	1898 Aug.	18	2414520	9·0	+0·1
12	1899 Jan.	9	2414664	8·9	0·0
13	June	8	2414814	8·9	0·0
14	Oct.	29	2414957	8·9	0·0
15	1900 Mar.	27	2415106	8·7	−0·2
16	Aug.	25	2415257	8·7	−0·2
17	1901 Jan.	24	2415409	8·7	−0·2
18	June	15	2415551	9·1	+0·2
19	Nov.	19	2415708	9·3	+0·4

It is not necessary to give prominence to the minor details of this investigation, which has for its purpose the determination of the elements of *S Carinæ* from the foregoing data. Indeed it would be tedious to do so. I may therefore confine myself to a statement of the main points and results of the investigation.

(1) If the dates of maximum or minimum phase be grouped in sets of three years, and if a mean period be obtained from each of these sets, there will appear evidence that the period of the star is subject to secular variation

It would seem that the cycle is completed in about nineteen years, or forty-five light periods, although on this matter the evidence is far from conclusive, as it must of necessity be, from

the limited period during which systematic observations have been made.

(2) Let now the following values be considered :—

$P + \Delta p$ = period of variation.

$T_M + \Delta t_M$ = epoch of maximum phase.

$T_m + \Delta t_m$ = epoch of minimum phase.

E = number of light periods dating from epoch.

J_M = Julian day of observed maximum (Table I. col. 3).

J_m = Julian day of observed minimum (Table II. col. 3).

We may regard the secular variation of period to be of the character represented by the expression

$$\kappa \cos (\phi E - M).$$

As a first approximation we take,

$$\phi = 8^\circ ;$$

that is, the cycle of perturbations is completed in forty-five light periods.

It is evident that, with regard to maxima determinations (Table I.), the relation between the foregoing quantities is set forth by the equation :—

$$(T_M + \Delta t_M) + E(P + \Delta p) + \kappa \cos (8^\circ\ E - M) = J_M \quad . \quad . \quad (1)$$

Let now
$$x = \kappa \cos M$$
$$= \kappa \sin M,$$

and equation (1) becomes for maxima determinations

$$\Delta t_M + E\Delta p + x \cos 8^\circ\ E + y \sin 8^\circ\ E = \{J_M - (T_M + EP)\} \quad (2)$$

and for minima determinations

$$\Delta t_m + E\Delta p + x \cos 8^\circ\ E + y \sin 8^\circ\ E = \{J_m - (T_m + EP)\} \quad (3)$$

Thirty-nine equations of condition, twenty for Table I. and nineteen for Table II., were constructed on this type, the following values being assumed :—

$$P = 149^d$$
$$T_M = 2415038^J$$
$$T_m = 2415112^J.$$

(3) It will suffice to state only the final results of the solution of the two sets of equations.

Maxima determinations.—A rigorous consideration of the twenty equations yielded the following values :—

$$\Delta p = -\overset{\mathrm{d}}{0{\cdot}29}$$
$$\Delta t_{\mathrm{M}} = -5{\cdot}57$$
$$x = +3{\cdot}74$$
$$y = -3{\cdot}56$$

that is,

$$\mathrm{P} + \Delta p = \overset{\mathrm{d}}{148{\cdot}71}$$
$$\mathrm{T_M} + \Delta t_{\mathrm{M}} = \overset{\mathrm{J}}{2415032{\cdot}4}$$

Secular variation

$$= \overset{\mathrm{d}}{5{\cdot}2} \cos (8^\circ\, \mathrm{E} - 316^\circ{\cdot}3).$$

Minima determinations.—A similar but quite distinct solution of the nineteen equations (Table II.) yielded the following values :—

$$\Delta p = -\overset{\mathrm{d}}{0{\cdot}28}$$
$$\Delta t_m = -4{\cdot}10$$
$$x = +1{\cdot}91$$
$$y = -3{\cdot}56$$

that is

$$\mathrm{P} + \Delta p = \overset{\mathrm{d}}{148{\cdot}72}$$
$$\mathrm{T}_m + \Delta t_m = \overset{\mathrm{J}}{2415107{\cdot}9}$$

Secular variation

$$= \overset{\mathrm{d}}{4{\cdot}1} \cos (8^\circ\, \mathrm{E} - 331^\circ{\cdot}7).$$

The close agreement between the results obtained from a separate consideration of the data in Table I. and the data in Table II. is strong presumptive evidence of the accuracy, not only of the value of the period obtained, but more especially of the amount and character of the secular variation.

Combining the two sets of results we have as the final and definitive values of the elements of *S Carinæ* :—

$$\mathrm{J_M} = \overset{\mathrm{J}}{2415032{\cdot}4} + \mathrm{E}\ \overset{\mathrm{d}}{148{\cdot}72} + \overset{\mathrm{d}}{4{\cdot}7} \cos (8^\circ\, \mathrm{E} - 324^\circ)$$
$$\mathrm{M} - m = \overset{\mathrm{d}}{73{\cdot}2}.$$

(4) In Tables III. and IV. is exhibited the amount of accordance between theory and observation.

The third column in both tables contains the observed dates

already given in Tables I. and II.; and the fourth column the dates computed from the elements just determined. The residuals are indicated in the last column.

TABLE III.

Maxima Observations.

Rotation No.	E.	Observed Date. J	Computed Date. J	O–C. d
1	–21	2411914·0	2411906·2	+7·8
2	19	2412206·0	2412204·6	+1·4
3	17	2412502·0	2412503·4	–1·4
4	16	2412645·0	2412652·8	–7·8
5	15	2412798·0	2412802·1	–4·1
6	14	2412958·0	2412951·4	+6·6
7	13	2413099·0	2413100·7	–1·7
8	11	2413396·0	2413399·4	–3·4
9	10	2413556·0	2413548·6	+7·4
10	9	2413701·0	2413697·7	+3·3
11	8	2413849·0	2413846·7	+2·3
12	3	2414587·0	2414590·8	–3·8
13	2	2414742·0	2414739·4	+2·6
14	– 1	2414887·0	2414887·8	–0·8
15	0	2415044·0	2415036·2	+7·8
16	+ 1	2415182·0	2415184·5	–2·5
17	2	2415334·0	2415332·7	+1·3
18	3	2415482·0	2415480·9	+1·1
19	4	2415626·0	2415629·0	–3·0
20	+ 5	2415772·0	2415777·1	–5·1

Mean residual $3^{d}\cdot8$

TABLE IV.

Minima Observations.

Rotation No.	E.	Observed Date. J	Computed Date. J	O–C. d
1	–20	2412137·0	2412130·9	+6·1
2	19	2412286·0	2412280·1	+5·9
3	18	2412422·0	2412429·4	–7·4
4	17	2412587·0	2412578·9	+8·1
5	16	2412727·0	2412728·3	–1·3

Rotation No.	E.	Observed Date. J	Computed Date. J	O—C. d
6	−15	2412875·0	2412877·6	−2·6
7	14	2413025·0	2413026·9	−1·9
8	12	2413327·0	2413325·6	+1·4
9	10	2413632·0	2413624·1	+7·9
10	9	2413774·0	2413773·2	+0·8
11	4	2414520·0	2414517·7	+2·3
12	3	2414664·0	2414666·3	−2·3
13	2	2414814·0	2414814·9	−0·9
14	− 1	2414957·0	2414963·3	−6·3
15	0	2415106·0	2415111·7	−5·7
16	+ 1	2415257·0	2415260·0	−3·0
17	2	2415409·0	2415408·2	+0·8
18	3	2415551·0	2415556·4	−5·4
19	+ 4	2415708·0	2415704·5	+3·5

Mean residual $3^{d}\cdot7$.

(5) In Tables I. and II. is given the libration on either side of the mean magnitude at maximum and minimum phase.

There was some expectation that this libration would, after the manner of the inequalities in period, follow some regular law.

It is evident, however, that the residuals given in the last column of Tables I. and II. are not systematic in their character; or, at any rate, there is so little evidence of systematic discordance that we may safely assume that it does not exist.

(6) It is pertinent to this investigation to relate the Cordoba observations of *S Carinæ* to those made at Lovedale.

Dr. Gould's observations are as follows :—

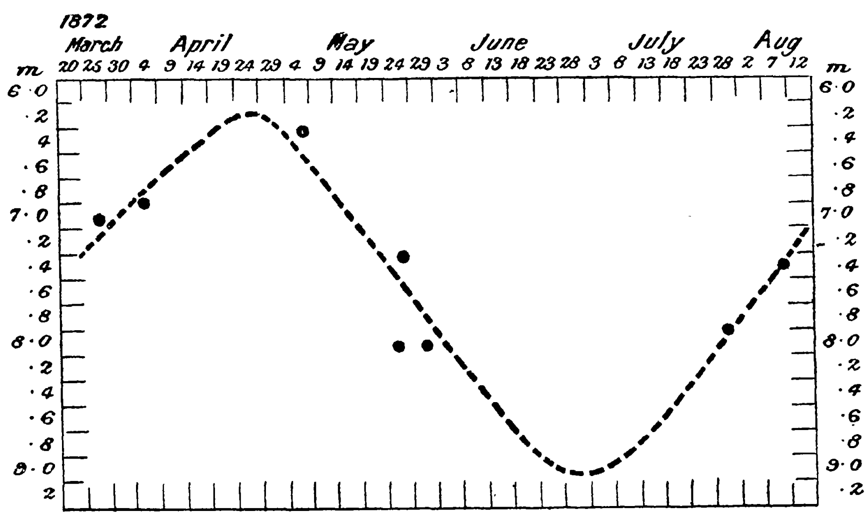
Observed Date.	Reduced Date.	Mag.
1872 Mar. 26	1872 Mar. 26	7·0
April 3	April 3	6 9
May 24	May 24	8·0
,, 30	,, 30	8·0
July 28	July 28	7·9
Aug. 7	Aug. 7	7·4
1874 May 21	May 6	6·3
June 9	,, 25	7·3

In the second column of the above table are given the dates of the first column reduced to one mean light period, that of March to August 1872.

Placed in order of time sequence, these observations are :—

	1872.	Mag.
1	Mar. 26	7·0
2	April 3	6·9
3	May 6	6·3
4	„ 24	8·0
5	„ 25	7·3
6	„ 30	8·0
7	July 28	7·9
8	Aug. 7	7·4

It is evident from the following chart that these eight observations indicate a maximum of $6^{m}\cdot2$ on or about 1872 April 24, and a mimimum of $9^{m}\cdot0$ on 1872 July 1.



Thus we have for an auxiliary determination of period :—

Maximum Phase.

		d.
Cordoba observations,	1872 April 24	= 2404910·0
Lovedale observations,	1900 Jan. 12·4	= 2415032·4
	Interval	= 10122·4

Minimum Phase.

		d.
Cordoba observations,	1872 July 1	= 2404976·0
Lovedale observations,	1900 March 28	= 2415107·9
	Interval	= 10131·9

If we take the mean interval between the Cordoba and the

Lovedale mean light curves as 10127 days, we find that sixty-eight periods are performed in this time, giving a mean period of

$$148^{d}\cdot 9.$$

This value is in satisfactory agreement with that found from Lovedale observations alone, viz.

$$148^{d}\cdot 72.$$

If we take a mean between these two values we shall arrive at a value of the period correct to within one-tenth of a day.

(7) In plates 9 and 10 are represented graphically the light changes of *S Carinæ* during the year 1901.

The main characteristics of the light curve are (1) the practically equal duration of the increasing and decreasing phases, and (2) the indistinct secondary maximum which takes place about forty days before primary maximum.

With regard to the equality that exists between decreasing and increasing phases, the numerical values are:—

	d.
Increasing phase	73·2
Decreasing phase	75·5
Difference	2·3

It has been shown that a similar tendency to equality between increasing and decreasing phase exists in the case of the long period *T Centauri* (*Monthly Notices*, vol. lxii. p. 69).

In this case the values are :—

	d.
Increasing phase	44·1
Decreasing phase	46·5
Difference	2·4

In neither of these instances, therefore, is a rapid ascent to maximum a feature of the star's variation. Similar instances could be multiplied, but these two definite determinations are sufficient to form an exception of some weight to the view which sometimes prevails that in all cases of long period variation the rise to maximum is very much more rapid than the fall to minimum.

The secondary maximum, which is of a very rudimentary character, is sometimes entirely absent. In one of the 1901 light curves there is only slight evidence of its existence. The phenomenon is therefore irregular in its nature.

Apart from this exception, however, all the other features of variation of *S Carinæ* are of marked regularity. Its return to maximum or minimum can be predicted within a few days; its limits of variation are subject to no erratic fluctuations, and there

is a certain general conformity to a common type of variation in all the light curves.

This common type is indicated in the plates which accompany this paper.

Lovedale: 1902 *February* 1.

New Variable Stars found during the Measurements for the Astrographic Catalogue at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

In the course of the measurement of the plates for the photographic map of the heavens, under Mr. Hollis's direction, a careful note is made of large differences of diameter of images of the same star on the overlapping plates which are measured simultaneously in the duplex micrometer.

The following four stars were in this way found to be variable, and their diameter on other plates were measured; the variability of the third one was announced by Dr. Anderson in 1897. The other three appear to be new :—

	Approx. R.A. 1900. h m s	Approx. Dec. 1900. ° ′
A	18 5 9	65 56·9
B	18 6 54	66 8·9
C U Draconis ...	19 9 42	67 7·1
D	5 49 22	74 30·8

A and B occur on the same plates; the following table gives their measured diameter (the unit being 0″·15) and that of neighbouring comparison stars whose magnitudes are taken from the *Bonn Durchmusterung* :—

No. of Plate.	Date.	Exp. m	A	B	66°1074 9·0	65°1238 9·5	66°1083 9·4	66°1079 9·5
411	1892 June 6	40	44	42	...	42	47	42
441	1892 „ 23	6	22	16	24	22	22	16
2117	1894 July 3	40	52	10	52	51	44	32
2688	1895 June 16	6	0	3	32	22	24	16
2697	1895 „ 17	6	0	0	...	25	22	13
2724	1895 „ 25	40	0	10	52	40	44	30
5088	1900 Sept. 13	6	16	0	22	22	22	20
5658	1901 June 6	40	21	3	41	33	38	26